TEACHER GUIDE
EXPLORE 1C LESSON 18

Food and Agriculture Center for Science Education

Module Questions: ***Why are there so many changes to my body during exercise? How does milk help with recovery from these changes?***

What We Figure Out:

By looking at research and data related to high-intensity exercise, we figure out how multiple different measurements of molecules in the body change over the course of high-intensity exercise:

- Muscle glycogen, a form of stored glucose that is a source of energy in cells, decreases during high-intensity exercise.
- Lactate, an energy source for cells in the body, levels in the muscle cells increase during exercise and return to a stable state at rest.
- pH, a measure of the acidity or alkalinity of a substance, in the muscle cells and in the blood decreases during high-intensity exercise.
- Epinephrine, a hormone that controls the fight-or-flight response, levels in the blood increase right away during high-intensity exercise.
- Liver glycogen, a form of stored glucose that is a source of energy in cells, is broken down to release glucose into the bloodstream during exercise.
- Blood glucose, an energy source for cells, levels increase during high-intensity exercise.

3D Learning Objective:	**Time estimate:**	**Materials:**
Students compare findings in multiple data sets to determine how high-intensity exercise changes levels of various molecules related to production and utilization of energy for exercise.	100 minutes	Lesson 18 Student Guide One Rep Max Video (optional) Lesson 18 Student Handout Data Sets 1-6 *Divide the total number of students by 6 and round up. This is the number of copies of each Data Set you will need to distribute.* ● Data Set 1 - Muscle Glycogen ● Data Set 2 - Lactate ● Data Set 3 - pH ● Data Set 4 - Epinephrine

		• Data Set 5 - Liver Glycogen • Data Set 6 - Blood Glucose Lesson 18 Teacher Resource Data Summary Slides 6 pieces of chart paper (2 per group) Markers (1 per student)

Targeted Elements

SEP:	DCI:	CCC:
DATA-H4: **Compare and contrast various types of data sets (e.g., self-generated, archival)** to examine **consistency of measurements and observations.**	**LS2.B-H1:** Photosynthesis and **cellular respiration (including anaerobic processes) provide most of the energy for life processes.**	**SC-H1:** **Much of science deals with constructing explanations of how things change and how they remain stable.**

Directions

Part 1: Our Motivation

USE OF PHENOMENA

Between Lessons 16-20, students will focus on the topic of exercise from the Module Phenomenon. In Lessons 21-22, they will focus on the topic of recovery from the Module Phenomenon. In Lesson 23, they will investigate a related phenomenon. They will return to the Anchor Phenomenon in Lesson 24 and revise their presentations to help their peers understand how milk can help them recover from exercise.

TEACHER SUPPORT

In this Our Motivation conversation, students may have many directions in mind or seem uncertain about where to go next. Embrace the idea of not necessarily having a consensus or a clear direction and acknowledge the uncertainty that comes with it. This is an opportunity to consider what investigations scientists in this area of study have done/are doing when they study exercise and its impacts on the body.

Return to class to explanations that students constructed in Lesson 17 Part 3: Constructing Explanations. Ask students to recall some of the ideas they had to explain the Module Question and some of the areas of uncertainty they had. Invite a few students to share what ideas the class had. Listen for responses such as:

- To bring air into and out of the body, we have to breathe. If we are producing more carbon dioxide during exercise, we have to breathe more often to get it out of our body. The faster we breathe, the more carbon dioxide we have to exhale.
- We saw that there is more oxygen in our blood going to our muscles. If we are breathing faster, then we are also bringing in more oxygen. The heart pumps blood, so if there is more oxygen in the blood and it needs to get to our muscles, the heart would need to pump faster to get it to those places quicker.
- We aren't really sure yet what the increases in oxygen and carbon dioxide consumption would have to do with muscles burning and fatiguing, getting energy for exercise, or how milk helps in recovery.

Acknowledge student responses and acknowledge the variety among them. Return to the Driving Question Board and highlight questions related to how the body uses energy for exercise, making energy, getting energy from milk, and if muscles get tired because they are running out of energy. Building off this conversation, suggest that students view data from scientists on several markers in the body that are commonly measured when studying changes in the body that occur as a result of exercise.

Students can record this on their Lesson 18 Student Guide Part 1: Our Motivation. This will help students understand how this lesson connects to what they were trying to figure out about the Module Phenomenon.

DCI SUPPORT

LS2.B-H1: Photosynthesis and **cellular respiration (including anaerobic processes) provide most of the energy for life processes.** While this lesson doesn't develop knowledge of this DCI explicitly, it serves as a stepping stone toward fully working with the highlighted portions of this DCI. In this lesson, students are exposed to measurable indicators of the body's metabolic responses to exercise or how it uses and produces energy for exercise. In this next lesson, students will build on the knowledge of how the levels of various molecular

factors change to figure out how the changes in these factors work together mechanistically to provide energy aerobically and anaerobically for exercise.

Part 2: Analyzing and Interpreting Data

Share with students that we have several data sets from peer-reviewed journal articles written by scientists who work in areas related to exercise science and human performance. Explain that each data set contains summaries of selections from two different scientific journal articles that investigate similar variables.

Each student will analyze and interpret the data sets from one of the six handouts. Note the options for students choosing a data set based on interest or assigning by interest and complexity in the teacher support box below. Share that students will compare the two studies to determine if their setup and findings are similar. Once students have chosen their desired data set topic, distribute the Lesson 18 Student Handout Data Sets 1-6 accordingly. Students can record their answers on their Lesson 18 Student Guide Part 2: Analyzing and Interpreting Data.

TEACHER SUPPORT

This is an opportunity for students to choose articles based on their interests or for you to assign them based on the complexity of the data set.

- If you choose to let student pairs choose data sets, here are some tips for how to do so:
  - List the data set number and article names at the front of the room for students to scan. Give students a moment of think-time to choose their first choice and second choice data sets.
  - Have students come to the board and sign their initials next to the data set that they choose.
  - Ensure that all data sets have at least two student pairs that choose it.
  - In case one data set is already selected by students, ask students to choose their second choice.
- If you choose to assign articles to students by complexity, use the suggestions below to differentiate your assignments.
  - **Data Set 3**: This data set is less complex than others. The data sets for blood glucose have similar methods. This data set might better lend itself to students who would benefit from being able to grasp one experiment and then note slight changes in the methods of the second investigation.

- **Data Set 4:** This set includes workout intensities that were determined by VO2 max in one study and based on one repetition maximum for another. Prompting a student to look closely at the total reps completed and the total power output may be useful.
- **Data Set 5:** This is likely the most complex data set. The data set has some small nuances that, with prompting, could allow for an opportunity for further sense making.
    - For example, one figure shows pH, and another shows the concentration of H+ ions. The ability to explain why these are measures of the same thing would be a chance for deeper sensemaking and a look at mathematical relationships.
    - Additionally, one study was able to measure both the interstitial pH levels and those of the surrounding blood. While the patterns in the data for those measurements are similar, prompting a student to think about the reason for the differences and why they might be important for scientists could be meaningful and contribute to sensemaking on a deeper level. These are specifically called out in the front material of the study. It would be an opportunity for a student to have a bit more exposure to scientific literature.

STUDENT SUPPORT

Students may be unfamiliar with the term "1 Rep Max," which plays a role in Data Set 2. If needed, have them reference this 25-second One Rep Max Video for an explanation of this term.

Allow students time to analyze the methods of the two experiments and the data presented. As students work, circulate the room to encourage students' thinking. Ask pressing questions such as:

- How were the two experiments designed? What methods were used? How are the designs similar/different?
- What were the objectives of the two experiments? How are they similar/different?
- What changes in oxygen use do you notice in each of the graphs?
- How do you think you can determine if the outcomes of the two studies are the same? What should you look for?

SEP SUPPORT

DATA-H4: Compare and contrast various types of data sets (e.g., self-generated, archival) to examine **consistency of measurements and observations.** In this lesson, students are analyzing the experiment design and outcome from two scientific research articles and determining if the findings are consistent. They are then summarizing the findings of their studies, sharing them with peers, and listening

to the summaries of studies from other groups. This builds on the experiences students have had in Module 1 when analyzing the methods and outcomes of single studies and on the experiences in Lesson 16 in comparing the findings of two studies for consistency.

CCSS SUPPORT

RST 9-10.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

Utilize the questions above to press students' thinking and help them make sense of the data presented. If students still need support determining the meaning of the data provided, encourage students to engage in conversation with one another to make sense of it.

FORMATIVE ASSESSMENT OPPORTUNITY

Students compare findings in multiple data sets to determine how high-intensity exercise changes levels of various molecules related to production and utilization of energy for exercise.

Assessment Artifacts:

- Students' comparison and analysis of two studies related to exercise and human performance (Lesson 18 Student Guide Part 2: Analyzing and Interpreting Data).

Look Fors:

- Students compare the methods by which the two data sets were collected (DATA-H4).
- Students compare the data shown in the two different studies and record what changes they notice to the quantity of the variable during intense exercise (specific to their data sets) and if these changes are consistent across studies (DATA-H4, LS2.B-H1, SC-H1).
- Students identify if the variable studied changes, to what degree it changes, and if the variable returns to its stable state (SC-H1).

Assessment Rubric:

	Emerging	Developing	Proficient
Sample Student Response	Comparison of Study Methods:	Comparison of Study Methods:	Comparison of Study Methods:

	Both of the studies looked at the amounts of glycogen in the muscles of people who exercised. Analysis of Study Conclusions & Consistency Both studies found that muscle glycogen decreases during exercise.	Study 1 included workouts at different intensities completed on cycles and used muscle biopsies to measure the muscle glycogen. Study 2 used elite athletes who completed a time trial for a cross-country ski course. Muscle biopsies were collected before and after the race to measure the amount of glycogen in the muscles using biochemical analysis. Analysis of Study Conclusions & Consistency Both studies found that muscle glycogen decreases during exercise. The study outcomes are consistent. Both show that the higher the intensity of the workout, the faster the muscle glycogen supply decreases.	Study 1 included workouts at different intensities completed on cycles, and the athletes were not noted as elite athletes. Each participant in that study also had two additional muscle biopsies taken during their workout. Study 2 used elite athletes who completed a time trial for a cross-country ski course. Muscle biopsies were collected before and after the race to measure the amount of glycogen in the muscles using biochemical analysis. Both studies measure changes in the amounts of muscle glycogen present in muscles before and during a workout. Analysis of Study Conclusions & Consistency The data from the first study shows that muscle glycogen decreases more rapidly in higher-intensity exercise, even when the workout is shorter than other workouts. Low-intensity workouts did not use much muscle glycogen compared to other intensities. The second study used a high-intensity workout, and you can see in the data that almost all of the muscle glycogen was used. We can see that glycogen in some areas of the cell was utilized more than others for this particular workout. The study outcomes are consistent. Both show that the higher the intensity of the workout, the faster the muscle glycogen supply decreases.
How to Achieve This Level	Student completes 0 out of 3 Look Fors	Student completes 1-2 out of 3 Look Fors	Student completes 3 out of 3 Look Fors

To Provide Additional Support for Students

Consider the following supports for students as they analyze the data sets:

- Ask students to explain the methods and data presented to identify similarities and differences.
- Hold a class discussion about what it means for two data sets to have similar methods and/or similar outcomes. Build a class definition of what to look for to determine if the two are similar.

- If a student seems overwhelmed, ask them to look at the figure and notice what is represented across the bottom (x-axis) on the side (y-axis). Then ask, "What does each line/bar represent?" Finally, focus on one line/set of bars and ask them to make a sentence describing what it is showing by using their answers to the previous question.
- Provide images showing people exercising on equipment used in the studies that may not be familiar to students.
- Use a more familiar example, such as if students were trying to determine if the same dish from two different restaurants tasted similar or different. Ask students what they would want to know from the restaurant and from the people eating the dish. Make an analogy to share that students would want to know if the preparation of the meal (the experimental methods) was similar and if the taste and overall enjoyment of the meal (the outcome of the experiment and what is measured) was either the same or was similar in nature (e.g., scrambled eggs prepared at two different restaurants can have different cooking temperatures, but the diners say the eggs from both places taste the same).
- Engage students in a peer feedback session. Provide students with the Look Fors, and use a protocol such as Tell-Ask-Give or norms such as SPARK. Students can use the Look Fors to provide feedback to each other on how they can improve selected Look Fors in their work.

Part 3: Sharing Our Findings

After students have analyzed the methods and data, remind students that six different sets of data were analyzed across the class. Share that students will now summarize what they found to share it with their peers so all students can understand the different changes happening during exercise. Ask students to meet in groups in which all students in the group chose the same data set. Allow students some time to summarize their findings in a way that will be understood by someone who did not read the study. Students can record this summary on chart paper so that all group members can participate in the discussion. Then, they can record the summary on their Lesson 18 Student Guide Part 3: Sharing Our Findings.

As students work, circulate the room to provide feedback and support for how students might be able to refine and simplify their summaries. Some ideas for providing feedback and supports include:

- Ask questions such as:
  - What part of the descriptions of the investigations can be combined? How about the data?
  - What commonalities exist between the methods and data collected between the studies?
  - How could this information be shared just once while pointing out any substantial differences worth noting?
  - Are there pieces of the description that could be simplified?

    - What could be restated to make it easier to understand? Who had something similar but perhaps clearer that we could adapt?
- Provide sentence stems such as:
    - I had something different in my notes for _____. Are we saying the same thing, or do we disagree?
    - The way you stated ____ makes me think of a question/another idea. Tell me if this would be useful.
    - So far, we didn't mention ____. I'm wondering if it is important to meet the goals of the summary or if it's just something I personally found interesting.
    - Have we included specific information about data that is interesting but does not need to be shared?

When students are finished preparing their summaries, have each group nominate a spokesperson to share their summaries with the class. Hold a whole-class discussion in which groups take turns sharing their summaries with the class and answering any questions from peers. Display the Lesson 18 Teacher Resource Data Summary Slides as a visual aid while each group is sharing their summaries with the class. The class can record the trends in changes in each data set and notes on their Lesson 18 Student Guide Part 3: Sharing Our Findings. Facilitate the discussion such that the class agrees on the following trends:

- Muscle glycogen levels decreased with higher-intensity exercise.
- Lactate levels increased with higher-intensity exercise and returned to a stable state with recovery.
- pH levels decreased with higher-intensity exercise and returned to a stable state with recovery.
- Epinephrine levels increased with higher-intensity exercise and returned to a stable state with recovery.
- Glucose released by the liver increased with higher-intensity exercise and did not return to a stable state.
- Blood glucose levels increased with higher-intensity exercise and returned to a stable state with recovery.

After the whole-class discussion, ask students to reflect on why they think it is helpful to analyze the findings from multiple scientific studies to determine if the findings are consistent. Acknowledge student responses. Build on responses to confirm that when you analyze the findings from multiple studies and discover that the outcomes are consistent, you can be more confident that the finding is reliable and not an accidental or mistaken finding due to potential errors in the way a single study was designed or carried out.

Finally, ask students to reflect on how the lens of stability and change helped them analyze the data in each of the studies. Use a Think-Pair-Share for students to share what they have found. Student responses may vary.

1. Students are given time to think independently about their responses.
2. Students find an elbow partner.
3. Students take turns sharing their thoughts with their partner. Each student should be given time to respond.

Facilitate the conversation such that students agree that:

- We looked at how the levels of these different factors changed during exercise and during recovery.
- We can conclude that many factors in the human body change during exercise and then return to a stable state. Others change and do not return to a stable state. Scientists study how these factors change and how they become stable when they study the human body.

CCC SUPPORT

SC-H1: Much of science deals with constructing explanations of how things change and how they remain stable. In this lesson, students viewed data on changes to several variables that exercise scientists commonly measure during rest, exercise, and recovery. This can allow them to reflect on how the study of the human body often involves figuring out measuring factors that remain stable (at rest), how the body changes in response to an external variable (such as exercise), and how the body returns to its stable state (in recovery).

Part 4: Constructing Explanations

Next, to begin navigation into the next lesson, ask students to try to explain any part of the Module Phenomenon (increased breathing rate, increased heart rate, and/or muscle burn and fatigue) using findings from this lesson. Students can record their ideas on their Lesson 18 Student Guide Part 4: Constructing Explanations. As students work, circulate the room to ask pressing questions such as:

- Look at the trends you observed in the data for each data set. How do the levels of these molecules change during exercise compared to rest?
- Are there any connections you can make between one data set and another?
- Think back to the Exercise Effects Model you created in Lesson 12. How do the changes you observed in the data relate to the different processes happening in the body during exercise (e.g., energy production, oxygen use, muscle function)?
- Reread your initial explanations for the changes we experience during/after exercise from Lesson 15. Can you revise your explanations based on the new data you analyzed?

Use a Think-Pair-Share for students to share what they have found. Student responses may vary here, and that is okay.

1. Students are given time to think independently about their responses.
2. Students find an elbow partner.
3. Students take turns sharing their thoughts with their partner. Each student should be given time to respond.

Acknowledge any student ideas that attempt to propose a mechanism that connects the change in one variable from this lesson to the change in another variable. For example:

- Blood glucose levels go up during exercise. I think this could be coming from the muscle and liver glycogen because they go down during exercise and glucose might be used during exercise for energy.
- When epinephrine levels increase, my heart feels like it is pounding.
- Decreasing muscle glycogen levels make muscles burn.

Conclude the conversation by emphasizing that students have many different ideas about how these variables could be related to the Module Phenomenon and that students will next ask questions that they want to figure out about these relationships.

Part 5: Asking New Questions

As a final step in this lesson, students will create a new list of questions to help them determine what additional information they need to know to help them figure out the Module Questions. They can write these questions on their Lesson 18 Student Guide Part 5: Asking New Questions. Add these questions to the appropriate category of the Driving Question Board so they can continue to be referenced in the coming lessons.

To facilitate students asking questions, use the Question Formulation Technique.

1. With their group, students take 5 minutes to brainstorm questions about what they need to know about increased breathing rate, increased heart rate, and/or muscle burn and fatigue.
2. Students then look at all their questions and choose the 3-5 questions they think are most important to be answered to help them figure out the Module Questions.
3. A representative from each group will then share their prioritized questions with the whole class. As students share their prioritized questions, they will add them to the Driving Question Board.

TEACHER SUPPORT

If a student is struggling to ask new questions, suggest the following sentence stems:

- Does the change in (*variable a*) cause (*variable b*) to change?
- What happens to _____ when _____ changes?

- Could _____ be the reason why _____ changes?
- How does a change in _____ cause _____?
- How does the body return _____ to a stable state?

LOOK FOR

In student responses, listen for the following ideas:

- Does epinephrine make my heart pound?
- Does epinephrine give me energy?
- Why do blood glucose levels go up? Is it used for energy during exercise?
- How much glucose is used by the cells for energy? Is it unlimited?
- Can you eventually use up your blood glucose?
- Do my muscles get tired when muscle glycogen levels are low?
- Do my muscles burn when lactate levels go up?
- Is there a connection between lactate and muscle fatigue?